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Sedimentation Values and Quality Characteristics of Hard Spring and Hard Winter Wheat Varieties

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Sedimentation Values and Quality Characteristics of Hard Spring and Hard Winter Wheat Varieties[1]

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Sedimentation tests of wheat and flour have been conducted for several years as a part of the Crops Research Division program to determine the characteristics of new wheat varieties and unnamed selections. The Hard Red Spring and Durum Wheat Quality Laboratory at Beltsville, Md., studied hard red spring wheat varieties primarily; whereas, the Western Wheat Quality Laboratory at Pullman, Wash., studied hard red winter and hard white wheats grown in the Pacific Northwest.

This report gives sedimentation, protein, and other quality data for hard wheat varieties grown in the northern Great Plains and the Pacific Northwest.

Many papers have been published relating sedimentation values to various wheat quality characteristics, especially protein content, dough properties, and suitability for bread making. Zeleny (29)[3] found a correlation of $\underline{r}$ = +0.79 between flour sedimentation and protein content of 117 hard red winter and 18 hard red spring varieties.

Pinckney, Greenaway, and Zeleny (23) reported correlations with protein ranging from $\underline{r}$ = +0.55 to 0.98 for groups of hard red winter, hard red spring, and hard white wheat commercial samples from nine crops beginning with 1947 (6,061 samples). Shellenberger (25) reported a correlation of wheat sedimentation with wheat protein content of $\underline{r}$ = +0.75 for the 359 samples of various market classes of wheat being imported into Europe from various countries. Harris and Sibbitt (17) reported a highly significant, although relatively low, correlation of $\underline{r}$ = +0.48 for the relation of wheat protein and wheat sedimentation.

Miller, Hays, and Johnson (19) found flour protein and sedimentation values from 60 hard red winter wheat samples of 5 varieties grown in 1953-54 and from 132 samples of 8 varieties grown in 1954-55 at several locations to be highly correlated, yielding coefficients of $\underline{r}$ = +0.61 and 0.75, respectively. Correlations of protein content and sedimentation vs. loaf volume and bread score on 429 commercial lots of 1960 and 1961 crops of hard red winter wheat were significant, and in most comparisons fairly high; but those for protein content were higher than those for sedimentation (Pratt, Thormby, and Schlesinger, 24). Mattern and Eastin (18) reported coefficients of $\underline{r}$ = +0.65 and 0.69 for correlations of loaf volume and sedimentation with protein content for samples of hard red winter wheat varieties from the 1961 crop in Nebraska.

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[1] Cooperative investigation of the Western Wheat Quality Laboratory, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture; the Washington Agricultural Experiment Stations, Pullman, Wash.; and the Hard Red Spring and Durum Wheat Quality Laboratory, Crops Research Division, Agricultural Research Service, Beltsville, Md.

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[3] Figures in parentheses refer to Literature Cited at end of publication.

Zeleny (29), who first described the method, pointed out that the poor quality varieties such as Chiefkan and RedChief could be detected. Later, Zeleny and others (31) and others (7, 15, 17, 23) found the method useful in characterizing the quality of known varieties. The method has been used by plant breeders to indicate selections most likely to have good bread-baking quality.

In work at the Grain Research Laboratory (2), Winnipeg, Canada, samples of similar protein level were chosen for comparisons of sedimentation value and strength. A correlation coefficient of $r = +0.88$ was obtained. Miller, Hays, and Johnson (19) reported on hard red winter varieties in commercial production. Their correlations of sedimentation with mixing characteristics, protein content, and loaf volume were generally significant but in most cases relatively low. No significant difference in sedimentation between varieties was found.

Barmore (4), in a study including one hard red winter and several white varieties, reported differences in flour sedimentation values for varieties at a uniform protein content. High and significant correlations between flour sedimentation values and flour protein content permitted adjusting the sedimentation values for differences in protein. There was some correlation of sedimentation values with the bread-flour ratings where ratings were based on absorption and on valorimeter readings.However, there was little or no correlation with bread-flour ratings based on mixing time and on loaf volume.

The sedimentation test has been studied in many foreign countries, including Argentina, Austria, Belgium, Czechoslovakia, Ecuador, Germany, Hungary, Italy, The Netherlands, New Zealand, Peru, Spain, and Sweden. Most of the data indicate that the sedimentation test is a useful index of strength for one or more of the important properties with which it is compared.

In a broad sense, nearly every study has shown some relation of sedimentation values to the overall quality of bread-type varieties and lots of wheat. However, some reports give evidence to the contrary. According to Halton, Baker, and Jones (16) and Sibbitt and Gilles (26), protein content may be a better indication of bread-making quality than the sedimentation test. One reason for this is that the variables have been removed from the method used to determine protein, but they have not been removed from the method used to determine sedimentation (27). In virtually all correlation studies reported, their values range roughly from 0.50 to 0.90, thus encompassing only about one-fourth to four-fifths of the variability involved in the quality values under observation.

WHEAT VARIETIES

It is commonly recognized by those closely associated with the grain trade that varieties of hard wheat differ materially in baking strength as measured by rheological methods and actual bread-baking tests. The U.S. Department of Agriculture has arranged the currently grown hard red spring wheat varieties into five groups, the hard red winter wheats into six groups, and the hard white wheats into two groups in approximate order of decreasing gluten strength (table 1[4]). Varieties of about equal strength are in the same group; the groups are listed in order of decreasing strength. Protein levels typical of the variety were assumed in the rankings. This classification is based on milling and baking tests made in laboratories of the USDA, State experiment stations, and commercial flour mills. Sedimentation values were not considered in arriving at this classification.

Strong wheats when in the normal protein range for bread-making pruposes and when grown under satisfactory conditions have medium to long mixing (dough developement) times and good overall bread-baking strength in terms of loaf-volume potentiality, dough-handling properties, and value for blending with weaker wheats. They have also shown medium to high sedimentation values. Weaker wheats have less tolerance to mixing, often lower loaf volumes, and generally lower sedimentation values than stronger wheats.

[4]Compiled by Crops Research Division, Agricultural Research Service, Beltsville, Md.

Table 1.--Classification of hard wheat varieties in order of decreasing gluten strength[1]

Group	Varieties
	HARD RED SPRING WHEAT
1	Cadet, Centana, Ceres, Conley, Justin, Pembina.
2	Canthatch, Marquis, Newthatch, Rival, Redman, Regent, Rushmore, Selkirk, Thatcher.
3	Chinook, Lathrop, Lee, Mida, Pilot, Renown, Rescue, Reward, Sawtana.
4	CT 231, Henry, Komar, Russell.
5	Spinkcota.
	HARD RED WINTER WHEAT
1	Bison, Comanche, Nebred, Quanah, Rodco, Tascosa, Tenmarq, Warrior.
2	Aztec, Cheyenne, Colorow, Columbia, Harveyland, Itana, Kaw, Oro, Ponca, Rio, Shoshoni, Tendoy, Turkey, Westmont.
3	Iohardi, Kharkof, Minter, Rego, Westar.
4	Blackhull, Concho, Crockett, Karmont, Newturk, Omaha, Ottawa, Pawnee, Triumph, Wichita.
5	Apache, BlueJacket, Cache, Wasatch, Yogo.
6	Chiefkan, Early Blackhull, RedChief.
	HARD WHITE WHEAT
1	Burt.
2	Ramona, Baart, White Federation.

[1] Varieties within each group are considered to be of approximately equal gluten strength.

MATERIALS AND METHODS

Sedimentation test data on the hard red spring wheat varieties were obtained by the standard method (23). The wheat was ground on Tag-Heppenstall [5] moisture meter rolls and sifted. Straight-grade flour from the Buhler experimental mill, as described in Cereal Laboratory Methods(1), was used in the tests on the hard red winter and white varieties. However, data on a number of hard red winter varieties were also obtained using Tag-Heppenstall milled flour. The method was described by Zeleny in 1947 (29) and modified by Pinckney, Greenaway, and Zeleny (23). Other tests based on the principle that gluten swells in lactic acid have been reported by Berliner and Koopman (6) and by Finney and Yamazaki (13). The bread-baking tests were made by a straight-dough rich formula (including shortening, nonfat dry milk solids, salt, sugar, yeast, malted wheat flour, and varying amounts of potassium bromate), essentially as described by Finney and Barmore (12) and by Fifield and others (10).

The hard red spring samples were pure varieties grown on experimental plots in Montana, North Dakota, Minnesota, South Dakota, and Wisconsin from 1955 to 1960. The hard red winter and hard white wheat samples were similarly grown on experimental plots in Washington, Oregon, Idaho, Montana, and Utah from 1951 to 1958.

[5] Reference to a company or product by name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others not mentioned.

RESULTS AND DISCUSSION

Hard Red Spring Wheat Varieties

Statistical comparisons of wheat protein content and sedimentation as quality indicators for reflecting bread-baking strength have been made of the hard red spring varieties. Basic data and statistical summaries are given in tables 2 to 9. The correlation coefficients for the relation of loaf volume to both wheat protein and wheat sedimentation are given in table 2. Nearly all are significant at the 1-percent level. Loaf volume was more highly correlated with protein content than with sedimentation in 15 of the 21 varieties, but the significance of the differences was not tested. One of the reasons for the generally higher coefficient for protein content vs. loaf volume is probably the higher precision of the protein determination compared to the sedimentation value. However, this is an indication that abnormal samples within a variety are not identified any better by sedimentation than by protein content. The correlations of mixing time with wheat protein are also listed in table 2, but only a few had significant values. Correlations of mixing time with sedimentation were generally below correlations of mixing time with protein content.

The scatter diagrams of wheat sedimentation values vs. wheat protein content for Conley (Fig. 1, A) and Lee (Fig. 1, B) are typical of the data for the hard red spring varieties. Each point represents one sample in a single year. The dispersion of points in the two figures shows that considerable variation is due to protein content, but deviations in sedimentation also occur at the same protein content. Statistical analyses indicated that the values calculated for the two varieties at 14.5-percent protein were significantly different.

These data, and those of other spring varieties examined, are summarized in table 3. The varieties are arranged in order of their estimated sedimentation value at 14.5-percent protein content. The correlations (table 3) show that there was a medium to high and significant correlation between protein content and sedimentation value. All 21 varieties had correlation coefficients that were significant at the 5-percent level and 14 of these were also significant at the 1-percent level.

The correlation coefficients ranged from +0.60 for Lee to +0.95 for Pilot and Karnvor. This means that where the regression equation was used for predicting the sedimentation value from the protein content, the poorest correlation--0.60 (Lee)--would account for 36 percent of the variability existing between these two variables, whereas the best correlations--0.95--would account for about 90 percent of the variability. The sedimentation value (table 3) for each 1-percent change in protein content, based on the regression equation, varied from 3.27 for Ceres to 10.26 for Lathrop.

The sedimentation values at 14.5 percent protein, and the confidence intervals for each variety, have been plotted in figure 2. According to these data, Rushmore has a significantly lower sedimentation value at 14.5-percent protein than does Pembina and Conley. Also, Lee and Henry have still lower values and are significantly different from Russell, Ceres, and Selkirk in addition to those varieties with values significantly higher than those for Rushmore. Spinkcota and Willet had distinctly lower quality than the other varieties.

Differences in environment frequently affect the protein levels of the varieties. Henry and Russell, grown in Wisconsin, usually are lower in protein content than are Conley, Thatcher, or Selkirk, grown in the more western part of the hard red spring wheat area. The Montana-grown varieties Centana, Rescue, and Chinook yield wheat of generally high protein content and have relatively strong gluten properties. Henry generally has lower protein content than the other varieties, no matter where it is grown.

TABLE 2.--Statistical comparisons of wheat protein and sedimentation as quality indicators

Variety	Samples	Correlation coefficients			
		Loaf volume vs. wheat protein	Loaf volume vs. wheat sedimentation	Mixing time vs. wheat protein	Mixing time vs. wheat sedimentation
	(No.)	HARD RED SPRING VARIETIES			
Ceres.....	8	0.89**	0.84**	+0.52	+0.49
Marquis.....	15	.66**	.52*	- .37	- .14
Pilot.....	8	.86**	.90**	+ .56	+ .42
Thatcher.....	94	.81**	.66**	- .46**	- .42**
Henry.....	26	.69**	.36**	- .07	- .14
Rushmore.....	16	.72**	.55**	- .28	- .08
Selkirk.....	86	.79**	.63**	- .37**	- .31**
Russell.....	16	.92**	.84**	- .08	- .12
Chinook.....	10	.60	.72*	+ .24	+ .61
Centana.....	7	.90**	.91**	+ .42	+ .33
Lee.....	92	.70**	.62**	- .33**	- .12
Rescue.....	13	.72**	.67**	+ .32	+ .56*
Mida.....	29	.78**	.74**	- .14	+ .01
Canthatch.....	25	.88**	.80**	- .20	+ .02
Pembina.....	14	.90**	.77**	- .87**	- .74**
Overby.....	7	.82*	.63	+ .30	+ .42
Lathrop.....	7	.77	.93	- .09	- .03
Karnvor.....	6	.95**	.88**	+ .82*	+ .92**
Conley.....	77	.82**	.64**	- .39**	- .31**
Spinkcota.....	5	.38	.70	- .26	- .63
Willet.....	5	.52	.64	+ .87	+ .81
All samples....	556	.75**	.64**	- .24**	- .15**
		HARD RED WINTER VARIETIES			
Itana.....	6	0.38	-0.05	-0.25	+0.47
Westmont.....	4	.97*	.73	- .74	- .37
Columbia.....	8	.77*	.63	- .46	- .32
Rio.....	6	.79	.61	- .46	- .33
Kharkof.....	7	.61	.41	- .42	- .01
Cheyenne.....	4	.10	- .03	- .10	+ .14
All samples....	[1] 40+	.67**	.49**	- .26	.00
		HARD WHITE VARIETIES			
Burt.....	8	0.44	0.07	-0.49	-0.01
Baart.....	9	.68	.60	- .09	+ .12
All samples....	17	.55*	.28	- .64**	+ .23

[1] Includes a few additional samples of varieties not listed.
*Significant at 5-percent level; **significant at 1-percent level.

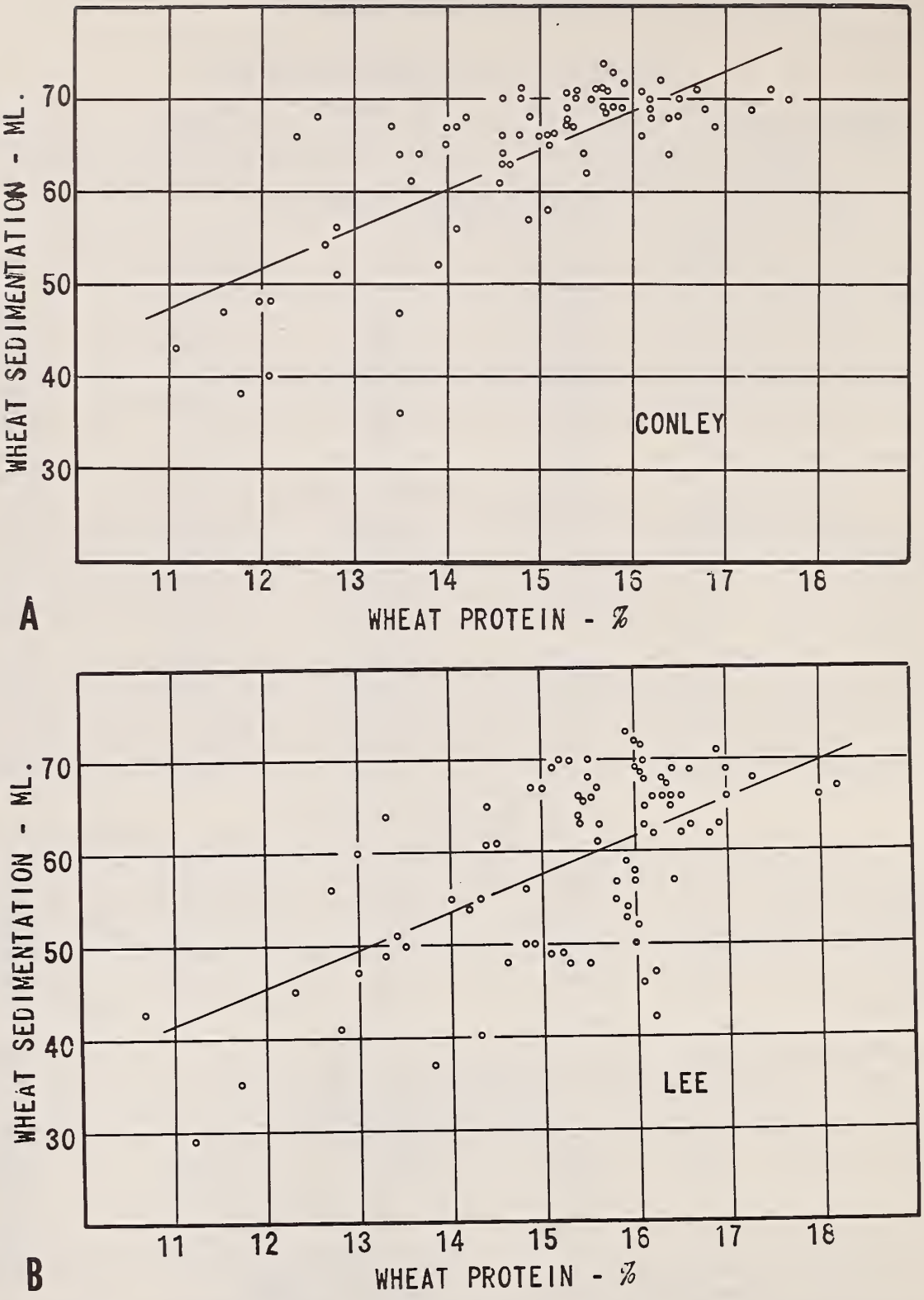

Figure 1.--Wheat sedimentation values vs. wheat protein content for the hard red spring wheat varieties: A, Conley, B, Lee.

TABLE 3.--Sedimentation values and protein contents of hard red spring wheat varieties.

Variety	Samples	Correlation coefficient	Mean sedimentation	Mean protein[1]	Sedimentation at 14.5 percent protein	Regression coefficient	Standard error of regression	Standard error of estimate
	No.		Ml.	Pct.	Ml.			
Karnvor.....	6	0.95**	56.6	12.9	[2] 66.6 ± 7.70	6.26	± 1.024	5.52
Pembina.....	14	.89**	67.1	15.2	63.6 ± 3.04	5.02	± .762	4.82
Rescue.....	11	.67*	68.4	15.6	63.4 ± 6.86	4.58	± 1.695	7.94
Russell.....	15	.91**	51.1	12.8	63.4 ± 4.76	7.22	± .940	5.87
Ceres.....	8	.80*	67.3	15.9	62.7 ± 4.18	3.27	± .984	2.82
Conley.....	76	.75**	64.1	14.9	62.4 ± 1.38	4.29	± .444	5.82
Lathrop.....	7	.90**	58.9	14.2	62.0 ± 4.34	10.26	± 1.814	4.22
Selkirk.....	81	.81**	61.8	14.6	61.2 ± 1.40	5.72	± .466	6.33
Centana.....	7	.85*	67.6	16.1	61.1 ± 6.66	4.04	± 1.098	5.03
Marquis.....	14	.67**	62.9	14.9	60.6 ± 4.06	5.72	± 1.844	6.40
Pilot.....	8	.95**	64.9	15.3	60.0 ± 3.18	6.08	± .782	3.21
Canthatch.....	25	.74**	60.2	14.8	59.5 ± 2.78	3.69	± .700	6.90
Thatcher.....	87	.79**	60.2	14.7	59.2 ± 1.44	5.14	± .429	6.69
Overby.....	7	.93**	56.1	14.1	59.0 ± 4.88	7.36	± 1.324	4.78
Mida.....	26	.69**	58.7	14.5	58.7 ± 2.56	4.02	± .857	6.33
Chinook.....	9	.75*	63.4	15.9	57.2 ± 6.54	4.42	± 1.481	5.47
Rushmore.....	15	.74*	58.0	14.7	57.1 ± 3.12	4.45	± 1.108	5.54
Lee.....	87	.60**	59.3	15.4	55.7 ± 1.99	4.03	± .582	7.94
Henry.....	27	.76**	40.9	12.8	49.3 ± 4.07	5.03	± .867	6.83
Spinkcota.....	5	.89*	50.4	16.3	33.4 ± 34.8	9.23	± 5.74	6.55
Willet.....	5	.92*	39.8	17.1	20.1 ± 16.25	7.59	± 1.900	2.95

[1] 14-percent moisture basis.
[2] Probability at the 5-percent level that the true sedimentation at 14.5-percent protein content will be in this range.
* Significant at 5-percent level, ** significant at 1-percent level.

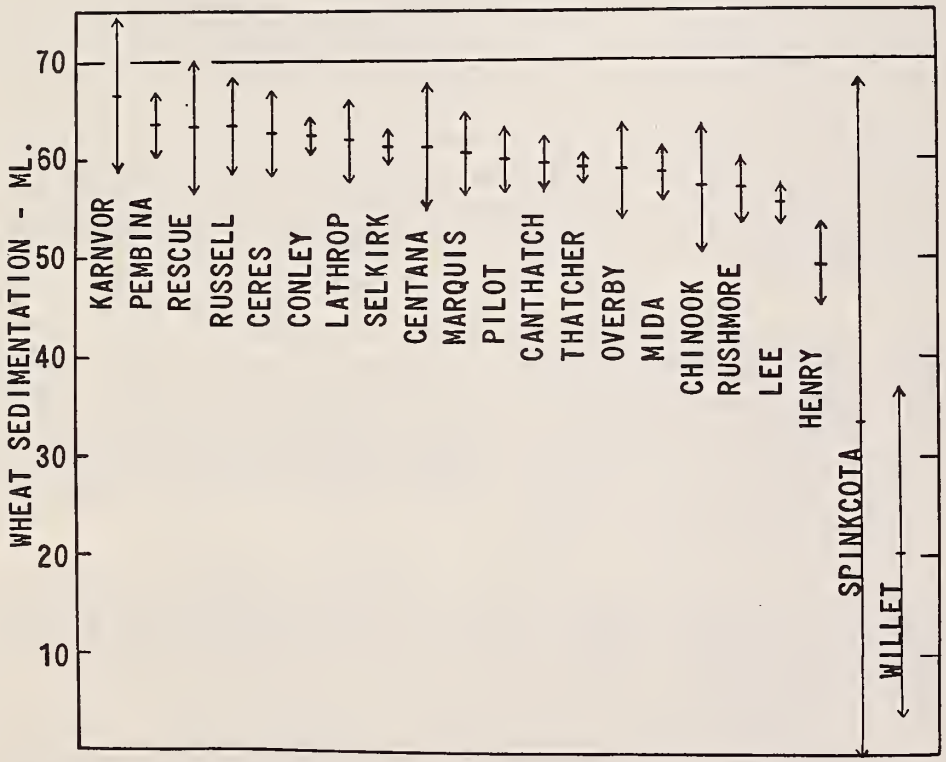

Figure 2.--Confidence intervals (at the 5-percent point) for the wheat sedimentation values at 14.5-percent wheat protein content for the hard red spring wheat varieties.

This difference in performance leads to some difference in rating of the varieties by the milling industry. Henry and Russell have been considered undesirable by some segments of the milling industry. Henry, when grown in Washington, had slightly less mixing strength than Turkey but was otherwise equal to it (20). Fifield, Weaver, and Hayes (11) in 1950 rated Henry high in loaf volume in view of the protein level but weak in dough-mixing properties. Russell has been classed as having fair quality (3). Lee was considered to be a good quality wheat variety by Fraser and Whiteside (14), but Lee and also Selkirk were found to be only fair in quality by Bequette, McNeal, and Potts (5). Lee, Selkirk, Conley, Pilot, Marquis, Ceres, Rushmore, and Thatcher were rated as satisfactory by Ausemus and Reitz (3). Pembina and Justin have been rated as bread wheats of good milling and baking quality (9, 28). Karnvor and Overby in collaborative tests (21) were shown to be deficient in milling and baking quality. Spinkcota, rated poor in bread-making qualities (3), often has been discounted on the market. Willet was never released for commercial growing because of its poor bread-making qualities (10, 21).

The relative rankings of the varieties by the most reliable data (those represented by 25 or more samples) in table 3 and figure 3 agree well with the ratings in table 1. Conley and Pembina in group 1 (table 1) have the highest sedimentations at 14.5-percent protein; Selkirk, Thatcher, and Canthatch in group 2 had slightly lower values, followed by Mida and Lee in group 3 and Spinkcota in group 5.

Russell has been placed in group 4 because, like Henry, it has a lower protein content than other varieties grown under comparable conditions. According to the sedimentation data, Russell appeared to have much better quality than Henry. Compared to the other varieties, Russell and Henry had large loaf volumes and long mixing times in view of their protein contents.

Rescue and Lathop also had high sedimentation values but were in group 3. These two varieties had relatively high loaf volumes but moderately low mixing times in relation to their protein contents, as compared to the other varieties. Rescue apparently has been rated low in table 1 because of low absorption (4). According to sedimentation, Lee should be in a lower group than 3. But, because it produces grain of higher protein content than that of other varieties, it performs better than the adjusted sedimentation values indicate. There is no apparent explanation for Lathrop being in group 3 with its high sedimentation value of 62.0, or for Rushmore being in group 2 with its low sedimentation value of 57.1. These two varieties are the only spring varieties in this study where sedimentation values contradict the general performance ratings as given in table 1.

The average sedimentation value of the varieties in Group 3 is essentially the same as that for the varieties in Group 2. This appears to be due to the relatively high sedimentation values of Lathop and Rescue. It may also be related to the fact that no more than 11 samples of these 2 varieties were studied. The sedimentation values for Russell in Group 4--63.4--and for Rushmore in Group 2--57.1--are contradictory. Data were studied on 15 samples of Russell and 7 samples of Rushmore. Henry, Spinkcota, and Willet have the lowest sedimentatin values and also have the poorest bread-baking strength.

The data presented here indicated that at a constant protein content level, the recognized inherent differences in gluten strength among hard red spring varieties tended to be reflected by their sedimentation values. These same general conclusions were further substantiated by data on the 1961 crop (30).

The value of the sedimentation test, as discussed in this paper, for predicting bread-baking quality has been based on sedimentation values adjusted to the same protein content and reported on a 14-percent moisture basis. Sedimentation values reflect both gluten quality and quantity. Hence, when dealing with wheat samples differing widely in gluten quality, sedimentation should

measure baking strength better than protein content, whether or not protein content also varies widely. Strength is a function of the properties of the protein and the amount present. Within one variety, gluten quality is usually fairly constant; hence, since the protein test is more precise chemically than is sedimentation, it would be expected, under these circumstances, that a better correlation would be obtained between protein and loaf volume than between sedimentation and loaf volume. Protein content, however, is a universally recognized factor related to baking strength.

Quality data for four hard red spring wheat varieties--Conley, Lee, Selkirk, and Thatcher--grown in Minnesota and Wisconsin in 1956 and in 1958-60 are shown in table 4.

To determine if the amount of protein was a varietal factor, the analysis of variance was made of data in table 4. Other varieties were not grown as many years at as many locations. The statistical constants obtained are shown in tables 5 and 6.

The loaf volumes, sedimentations, and mixing times given in table 6 were adjusted by means of the regression coefficients to the mean protein content--13.6--of the four varieties, since the correlations were highly significant (tables 2 and 3).

Lee differed in mean protein content from the other three varieties. Lee and Thatcher had about the same mean loaf volume and would be judged equal in strength by this test. However, this is a false conclusion because the adjusted loaf volumes indicated a highly significant difference in loaf volumes.

According to the mean sedimentation values, Thatcher was lower than Lee; but after adjustment, their mean values were essentially the same. Thus, sedimentation values for these two varieties, after adjustment for differences in protein content, disagree with the corrected loaf volumes, but agree with the ratings of these two varieties in table 1. Doubtless the reason for some of the confusion about the ranking of Lee compared to other hard spring varieties is due to the endency of Lee to produce grain of high protein content. Some workers probably give more weight to protein content than to loaf volume or mixing time, and vice versa. There was no significant difference in either the mean or the adjusted mixing times of these two varieties.

Differences in the mean loaf volumes of Conley and Selkirk were not large enough to be significant, and adjustment for the nonsignificant difference in mean protein content is hardly justified. However, the sedimentation values were higher for Conley than for any of the other three varieties. This would indicate that Conley is a stronger variety than the others, which is also indicated by the mixing times and the ranking in table 1. This, however, is not borne out by differences in loaf volume.

Since Henry, Thatcher, Lee, and Selkirk were grown at Madison, Wis., each of 6 years (1955-60), the mean protein contents, loaf volumes, sedimentations, and mixing times were studied (table 7). Madison was the only location where these four varieties were grown for more than 5 years. The adjusted values were calculated by means of the statistical constants obtained for these varieties in the analysis of the entire Hard Red Spring wheat data, and are shown in table 8.

The mean protein contents and the mean and adjusted loaf volumes and sedimentation values of Selkirk, Thatcher, and Lee tell the same relative story as the same values in table 6. Mixing time data indicate that Lee has a longer mixing time than Selkirk and Thatcher. Henry illustrates the opposite characteristics to Lee; it had a significantly lower mean protein content than the other varieties. On the basis of the observed mean loaf volume, sedimentation, and mixing time, it was the weakest variety of the four. However, after adjusting the values to a mean protein content of 13.8 percent, it had a loaf volume equal to Selkirk and Thatcher and considerably larger than Lee. Adjusted sedimentation produced essentially equal values for Henry, Lee, and Thatcher and a higher value for Selkirk.

Table 4.--Quality data for 4 hard red spring wheat varieties grown in Minnesota and Wisconsin, 1956 and 1958-60

Year, location and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf Volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
1956					
Waseca, Minn.:					
Conley	14.6	13.4	2.50	64	848
Lee	15.6	15.0	2.75	67	900
Selkirk	15.2	14.1	2.00	62	975
Thatcher	14.9	13.5	2.25	62	903
Crookston, Minn.:					
Conley	13.6	12.8	2.50	61	890
Lee	13.3	12.2	2.00	49	845
Selkirk	12.0	11.2	2.25	39	833
Thatcher	11.9	11.5	2.25	43	823
Madison, Wis.:					
Conley	14.8	13.5	2.75	66	938
Lee	16.6	15.4	2.25	63	943
Selkirk	15.6	14.6	2.00	66	950
Thatcher	14.3	13.3	2.00	56	940
1958					
Waseca, Minn.:					
Conley	12.7	12.1	2.75	54	788
Lee	14.5	13.5	2.75	61	825
Selkirk	13.8	13.0	2.50	57	828
Thatcher	13.2	12.4	2.75	60	805
Crookston, Minn.:					
Conley	12.0	11.1	2.50	48	760
Lee	12.7	12.0	2.00	56	748
Selkirk	11.2	10.8	2.25	42	728
Thatcher	11.6	10.8	2.00	48	723
Madison, Wis.:					
Conley	12.8	11.8	2.75	51	728
Lee	13.5	12.2	2.00	50	743
Selkirk	12.1	11.4	2.25	42	770
Thatcher	12.2	11.2	2.25	39	735
1959					
Waseca, Minn.:					
Conley	12.4	11.8	2.75	66	750
Lee	13.3	12.7	2.50	64	805
Selkirk	12.9	12.6	2.75	66	785
Thatcher	12.4	11.5	3.00	54	763

See footnote at end of table.

Table 4.--Quality data for 4 hard red spring wheat varieties grown in Minnesota and Wisconsin, 1956 and 1958-60--Continued.

Year, location and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf Volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
Crookston, Minn.:					
Conley	15.3	14.5	2.75	67	930
Lee	15.5	15.0	3.00	64	925
Selkirk	15.2	14.8	2.50	63	928
Thatcher	13.9	13.5	3.00	64	908
Madison, Wis.:					
Conley	15.8	15.0	2.75	73	905
Lee	16.0	15.0	2.75	58	835
Selkirk	15.8	15.0	2.25	65	895
Thatcher	15.1	14.3	2.50	62	855
1960					
Waseca, Minn.:					
Conley	14.5	13.7	2.50	61	890
Lee	14.6	13.9	3.00	48	885
Selkirk	15.3	14.6	2.75	60	945
Thatcher	13.3	12.4	3.00	42	858
Crookston, Minn.:					
Conley	11.8	10.9	3.75	38	775
Lee	11.2	10.4	3.00	29	688
Selkirk	10.5	9.8	2.75	29	725
Thatcher	10.9	10.3	3.75	28	725
Madison, Wis.:					
Conley	13.9	13.0	3.00	52	785
Lee	12.8	11.5	3.00	41	755
Selkirk	13.2	12.8	2.25	42	815
Thatcher	12.7	11.9	2.75	37	775

[1] 14-percent moisture basis.

Henry has generally been classed as undesirable in the hard spring wheat area. This could be due, in part, to its characteristically low protein content, but it is questionable if this is a sound basis for such a classification. Adjusting the mixing times did not change the small and nonsignificant differences between Selkirk and Thatcher but it did appear to increase that of Lee to a value that was significantly longer than that for Selkirk. These data do not agree with some other reports (4, 28), although no adjustments for differences in protein content were made in these other reports.

To determine the relative value of ranking hard red spring varieties by protein content or by sedimentation and loaf volume comparisons were made of the relative rank of samples from individual stations each year (tables 9 and 10). The data compared were for 285 samples of from 4 to 7 varieties, grown at 7 stations nearly every year for 6 years. The correlation between the

Table 5.--Statistical constants derived from analysis of data for quality characteristics in hard red spring wheat

Quality factor	Standard error of variety means	Least significant difference at 5-percent level
Wheat protein--pct.....	0.126	0.40
Mixing time--min.....	.070	.227
Sedimentation--ml.....	1.20	3.85
Loaf volume--ml.....	6.01	19.7

Table 6.--Mean and adjusted values indicating quality of four spring wheat varieties

Variety	Wheat Protein Mean[1]	Loaf volume		Sedimentation		Mixing time	
		Mean	Adjusted	Mean[1]	Adjusted	Mean	Adjusted
	Pct.	Ml.	Ml.	Ml.	Ml.	Min.	Min.
Conley.....	13.7	831	826	58.4	58.0	2.77	2.78
Lee.....	14.1	825	806	54.2	52.2	2.58	2.62
Selkirk.....	13.6	848	848	52.7	52.7	2.37	2.37
Thatcher.....	13.0	818	846	49.6	52.7	2.62	2.55

[1] 14-percent moisture basis.

rankings by protein content and by loaf volume was slightly higher (r = +0.56) than the correlation between the rankings by sedimentation and loaf volume (r = +0.47). Thus, in these data, protein content appeared to be a slightly more reliable prediction of loaf volume than did sedimentation.

According to these data, neither sedimentation alone nor in conjunction with protein content nor protein content alone satisfactorily predicted loaf volume or mixing time where differences were small, as in these samples. Where there were 25 or more samples of a variety, the mean sedimentation, after adjusting to a uniform protein content, indicated the relative bread-baking value as set forth in table 1.

Hard Red Winter and Hard White Wheat Varieties

Data on two groups of hard red winter wheat varieties were obtained. The first group consisted of 50 samples of 7 varieties from the 1954 to 1960 crops. Both Buhler-milled flour and "Tag" flour sedimentation data were obtained. Flour protein averaged 11.5-percent and wheat protein 12.5-percent. The correlation and regression coefficients between methods (with Buhler flour sedimentation as the dependent variable) were r = +0.95 and 1.291, respectively. Tag flour sedimentation (x) was found to be related to Buhler flour sedimentation (y), according to the equation X = 0.679 Y -0.40. This equation shows that the sedimentation values from Tag flour were considerably lower than those from Buhler-milled flour. Data on the hard red winter and white wheats appear in tables 11 and 12. The correlation was high between the results by the two methods; therefore, it was considered best to emphasize the Buhler-milled flour sedimentation

TABLE 7.--Quality data for hard red spring wheat varieties grown at Madison, Wis., 1955-60

Year and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
1955:					
Henry	11.4	10.8	2.00	26	716
Thatcher	13.7	12.8	2.25	45	797
Lee	15.2	13.6	2.00	49	813
Selkirk	14.7	13.8	2.25	60	896
1956:					
Henry	13.6	12.6	2.00	46	930
Thatcher	14.3	13.3	2.00	56	940
Lee	16.6	15.4	2.25	63	943
Selkirk	15.6	14.6	2.00	66	950
1957:					
Henry	12.4	10.8	1.75	38	763
Thatcher	13.8	12.3	2.50	43	915
Lee	14.9	13.9	2.25	50	825
Selkirk	14.1	13.5	2.00	50	903
1958:					
Henry	10.9	9.7	1.50	30	710
Thatcher	12.2	11.2	2.25	39	735
Lee	13.5	12.2	2.00	50	743
Selkirk	12.1	11.4	2.25	42	770
1959:					
Henry	13.9	12.7	2.25	49	790
Thatcher	15.1	14.3	2.50	62	855
Lee	16.0	15.0	2.75	58	835
Selkirk	15.8	15.0	2.25	65	895
1960:					
Henry	12.9	11.6	2.50	38	803
Thatcher	12.7	11.9	2.75	37	775
Lee	12.8	11.5	3.00	41	755
Selkirk	13.2	12.8	2.25	42	815

[1] 14-percent moisture basis.

values because there were over 200 samples representing the same varieties in each of the years from 1951 to 1958 in this group.

Figure 3, A and B illustrate the relationship of flour sedimentation values to protein content at similar protein levels for the hard red winter varieties Rio and Wasatch. These varieties were chosen because they differ appreciably in quality. Table 11 and Figure 4 summarize the data for the hard red winter and hard white wheats. The 10.5-percent flour protein was chosen as a level for comparison.

Table 8.--Mean and adjusted values indicating quality of the string wheat varieties Henry, Thatcher, Lee, and Selkirk

Variety	Wheat protein	Loaf volume		Sedimentation		Mixing time	
	Mean[1]	Mean	Adjusted	Mean[1]	Adjusted	Mean	Adjusted
	Pct.	Ml.	Ml.	Ml.	Ml.	Min.	Min.
Henry.....	12.5	785	851	38	45	2.00	([2])
Thatcher.....	13.6	836	845	47	48	2.38	2.36
Lee.....	14.8	819	781	52	48	2.38	2.47
Selkirk.....	14.2	871	852	54	52	2.17	2.20

[1] 14-percent moisture basis.
[2] Not calculated because the r value for mixing time vs. wheat protein of Henry was not significant.

With hard red winter and hard white wheat varieties, as with hard red spring varieties, flour sedimentation values reflect variety characteristics that are highly related to protein content. Also, there are differences among varieties. Kharkof and Rio at 10.5-percent protein content had significantly lower values than Itana; similarly, Wasatch and Yogo had values significantly below those of Itana, Westmont, Columbia, and Rio. The confidence intervals for Cheyenne are large, making it impossible to conclude that it is different from the other good quality hard red winter wheats or from the poor quality Wasatch. Burt, a hard white winter variety, gave a flour sedimentation value at 10.5-percent protein content similar to Columbia and Rio; the hard white spring variety Baart was much lower and similar to the Yogo variety of hard red winter.

The rating of the varieties studied according to the flour sedimentation values at 10.5-percent protein corresponds with the grouping in table 1 except that Cheyenne and Kharkof have the same sedimentation value--(51.3), but the former is in group 2 and the latter in group 3. This difference in grouping is due to the very strong mixing properties of Cheyenne; otherwise, it probably would be in group 3 or 4. Cheyenne does not have the loaf volume potential of Kharkof, and Kharkof does not have the mixing strength of Cheyenne. The Rio variety is the western area's representation of the Turkey type and is in group 2, although the sedimentation value is only slightly higher (but not significantly higher) than Kharkof in group 3. Rio does have stronger mixing properties and a higher loaf volume potential than Kharkof. Columbia, with a sedimentation of 55.5, and Itana with 59.9, are in group 2. Wasatch, with 37.2, and Yogo, with 28.9, are in group 5. Wasatch and Yogo have been considered less desirable than the other hard red winter varieties shown in table 11.

Sedimentation values of the two hard white varieties studied classify them correctly according to table 1. Burt, with a sedimentation value of 54.3, is in group 1; and Baart, with 31.7, is in group 2. Baart has a very short mixing time and very little mixing tolerance. Certain millers (8, 22) interested in the quality of western wheats reported ratings several years ago of some of the varieties studied here, as follows: Baart, excellent; Rio, Columbia, Itana, good; Burt, fairly good; Yogo, fair. Baart is not well suited for use in present day bread flours because it lacks mixing strength. It was used widely before World War II in blends with strong hard red winter and spring varieties partly because it had a desirable effect on bread color. It is no longer used extensively in baker's bread flour.

TABLE 9.--Quality data for 4 hard red spring wheat varieties grown in North Dakota, 1956-59

Location, year, and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
Langdon					
1956:					
Thatcher	13.9	12.9	2.75	61	885
Lee	14.4	13.4	2.25	65	865
Selkirk	13.8	12.7	2.50	64	845
Conley	13.4	12.8	2.50	67	830
1957:					
Thatcher	14.7	13.6	2.75	70	935
Lee	16.0	14.6	2.50	69	980
Selkirk	15.6	14.4	2.50	70	945
Conley	14.8	13.4	2.75	70	903
1958:					
Thatcher	13.8	12.9	2.25	68	798
Lee	14.9	13.9	2.50	67	890
Selkirk	13.5	12.8	2.50	68	855
Conley	14.2	13.3	2.75	68	855
1959:					
Thatcher	14.2	13.1	2.75	53	855
Lee	15.0	14.3	3.00	67	855
Selkirk	14.3	13.8	2.75	67	845
Conley	14.0	13.2	3.00	67	850
Dickinson					
1956:					
Thatcher	15.3	15.0	2.00	70	1,025
Lee	15.3	14.9	2.25	70	970
Selkirk	15.5	14.7	2.00	71	1,048
Conley	16.0	15.8	2.25	72	1,010
1957:					
Thatcher	14.9	13.9	2.00	66	908
Lee	16.0	14.6	1.75	52	880
Selkirk	15.0	14.1	2.50	67	873
Conley	15.3	14.1	2.00	67	903
1958:					
Thatcher	14.2	13.5	2.25	61	860
Lee	15.9	15.0	1.75	54	898
Selkirk	14.6	13.9	2.00	63	840
Conley	15.1	14.2	2.00	58	880

[1] 14-percent moisture basis.

TABLE 9.--Quality data for 4 hard red spring wheat varieties grown in North Dakota, 1956-59--Continued.

Location, year, and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
Dickinson--Cont.					
	Pct.	Pct.	Min.	Ml.	Ml.
1959:					
Thatcher	16.1	15.3	2.00	66	928
Lee	16.5	15.5	2.25	62	925
Selkirk	14.9	14.3	2.50	68	865
Conley	16.4	14.5	2.25	68	948
Edgeley					
1956:					
Thatcher	12.7	12.1	2.75	67	850
Lee	14.3	13.4	3.00	55	910
Selkirk	13.1	12.2	2.50	68	848
Conley	12.6	11.9	3.00	68	823
1957:					
Thatcher	15.6	14.2	2.75	70	855
Lee	16.4	15.4	2.00	65	865
Selkirk	15.0	15.0	2.50	70	865
Conley	15.8	14.6	2.25	69	893
1958:					
Thatcher	13.4	12.4	2.25	62	795
Lee	14.4	13.5	2.25	61	818
Selkirk	13.2	12.7	2.25	60	785
Conley	13.5	12.6	2.50	64	815
1959:					
Thatcher	14.6	14.1	2.00	64	903
Lee	16.4	15.8	2.00	57	935
Selkirk	15.2	14.9	2.00	67	938
Conley	14.6	14.3	2.25	63	878
Fargo					
1956:					
Thatcher	14.4	13.8	2.00	68	920
Lee	15.1	13.9	2.50	69	908
Selkirk	14.6	13.7	2.25	70	983
Conley	14.6	13.9	2.75	70	920
1957:					
Thatcher	12.8	11.9	2.75	50	810
Lee	13.4	12.1	2.50	51	795
Selkirk	13.0	11.9	3.00	49	845
Conley	13.7	12.7	2.75	64	808

TABLE 9.--Quality data for 4 hard red spring wheat varieties grown in North Dakota, 1956-59--Continued.

Location, year, and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
Fargo					
1958:					
Thatcher	10.7	9.8	3.00	37	693
Lee	10.7	10.0	3.00	43	683
Selkirk	10.3	9.6	3.00	36	690
Conley	11.1	10.2	3.25	43	705
1959:					
Thatcher	12.1	11.7	3.50	45	758
Lee	13.0	12.2	3.00	47	773
Selkirk	12.5	11.8	2.75	44	793
Conley	12.1	11.6	3.50	48	760
Minot					
1956:					
Thatcher	14.8	14.5	2.25	70	973
Lee	15.5	14.7	2.50	70	960
Selkirk	14.2	13.2	2.25	67	930
Conley	15.4	14.8	2.75	71	970
1957:					
Thatcher	15.0	14.2	2.50	62	1,005
Lee	16.0	14.8	2.25	69	953
Selkirk	15.3	14.5	2.50	69	980
Conley	15.7	14.6	3.00	69	1,033
1958:					
Thatcher	14.6	13.4	1.75	66	825
Lee	15.9	14.6	1.75	73	860
Selkirk	14.2	13.6	2.25	68	820
Conley	15.3	14.1	1.75	69	930
1959:					
Thatcher	16.2	15.6	2.50	47	935
Lee	16.2	15.6	2.50	42	898
Selkirk	15.3	14.7	2.50	54	910
Conley	16.2	15.4	2.75	70	995
Williston					
1956:					
Thatcher	16.5	16.0	2.00	68	1,080
Lee	16.3	15.3	2.50	68	1,008
Selkirk	15.5	14.8	2.25	68	995
Conley	16.2	15.8	2.50	68	1,075

TABLE 9.--Quality data for 4 hard red spring wheat varieties grown in North Dakota, 1956-59--Continued.

Location, year, and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
Williston--Cont.	Pct.	Pct.	Min.	Ml.	Ml.
1957:					
Thatcher	17.8	17.2	1.75	71	1,183
Lee	18.2	17.0	1.75	67	995
Selkirk	17.6	16.8	2.50	72	1,175
Conley	17.7	16.4	2.75	70	1,170
1958:					
Thatcher	16.8	15.7	2.25	71	903
Lee	16.9	16.1	2.50	71	905
Selkirk	14.6	14.0	2.50	71	855
Conley	16.3	15.4	2.25	72	910
1959:					
Thatcher	18.2	17.0	1.75	69	923
Lee	19.5	18.6	2.50	63	950
Selkirk	16.8	16.3	2.50	60	920
Conley	19.5	18.2	2.75	70	1,030

The flour sedimentation ratings agree with the above ratings for Rio, Columbia, Itana, and Yogo, but not for Burt. Burt is a new hard white variety that was available to the milling industry for two crops before the January 1959 report (22). It is the opinion of the authors that a rating of Burt in 1963 would be higher.

To illustrate the relation of flour sedimentation to flour quality, the flour data on the two varieties Rio and Wasatch are shown in tables 12 and 13.

These data show that at similar protein levels flour sedimentation distinguished Rio from Wasatch in all but 7 of the 69 samples. Five Rio samples had low and two Wasatch samples had high sedimentation values. Protein content did not distinguish between the two varieties. Wasatch is a smut-resistant, hard red winter wheat variety that has been widely grown in Utah and southern Idaho. Rio is a Turkey type wheat grown in the Pacific Northwest. Rio has been considered a satisfactory bread-type variety, in contrast to Wasatch, which is inadequate in mixing strength and low in loaf volume capacity. The relations of protein content and sedimentation values to valorimeter reading in Brabender units, mixing time, and loaf volume for Rio and Wasatch are shown graphically in Figures 5 to 10.

Sedimentation values determined either from Buhler or Tag flours appear to be varietal characteristics. Consequently, sedimentation testing of hard red winter wheat should aid in identifying the best quality bread-making varieties.

While both sedimentation and protein may sometimes indicate bread-making quality, the final choice of testing method may rest with still other factors such as simplicity of procedure, chemicals, equipment, and time required for each test.

Table 10.--Quality data for 7 hard red spring wheat varieties grown in the advanced yield nursery in Montana, 1956-59

Year and variety	Protein[1]		Mixing time	Sedimentation[1]	Loaf volume
	Wheat	Flour			
	Pct.	Pct.	Min.	Ml.	Ml.
1956:[2]					
Thatcher	16.8	16.0	2.25	71	1,075
Lee	16.3	15.5	2.00	68	950
Selkirk	15.4	15.1	2.00	72	1,013
Conley	16.1	15.5	2.50	73	983
Centana	16.8	15.9	2.25	71	1,013
Chinook	16.1	15.6	2.25	70	975
Rescue	16.5	15.8	2.00	72	1,043
1957:[3]					
Thatcher	15.7	15.0	2.25	68	928
Lee	16.2	14.4	1.75	62	925
Selkirk	14.6	13.5	2.25	67	870
Conley	15.6	14.3	1.75	71	953
Centana	14.8	13.8	2.25	64	893
Chinook	15.3	14.7	2.00	64	848
Rescue	14.9	14.0	2.00	70	960
1958:[4]					
Thatcher	16.2	15.6	2.00	67	925
Lee	16.5	15.7	2.25	66	968
Selkirk	15.4	14.5	2.00	65	865
Conley	16.2	15.6	2.25	69	930
Centana	16.2	15.4	2.00	72	933
Chinook	15.9	15.4	2.25	65	853
Rescue	15.9	15.2	2.25	72	895
1959:[5]					
Thatcher	17.3	16.4	2.00	74	975
Lee	17.0	16.2	2.25	69	838
Selkirk	17.3	15.4	2.00	74	883
Conley	17.5	16.5	2.75	71	920
Centana	17.5	16.5	3.00	72	1,013
Chinook	16.4	16.0	2.50	68	880
Rescue	16.5	15.7	2.00	74	938

[1] 14-percent moisture basis.
[2] Composite of grain from Moccasin, Havre, and Huntley.
[3] Huntley only.
[4] Composite of grain from Huntley and Moccasin.
[5] Composite of grain from Huntley, Moccasin, and Sidney.

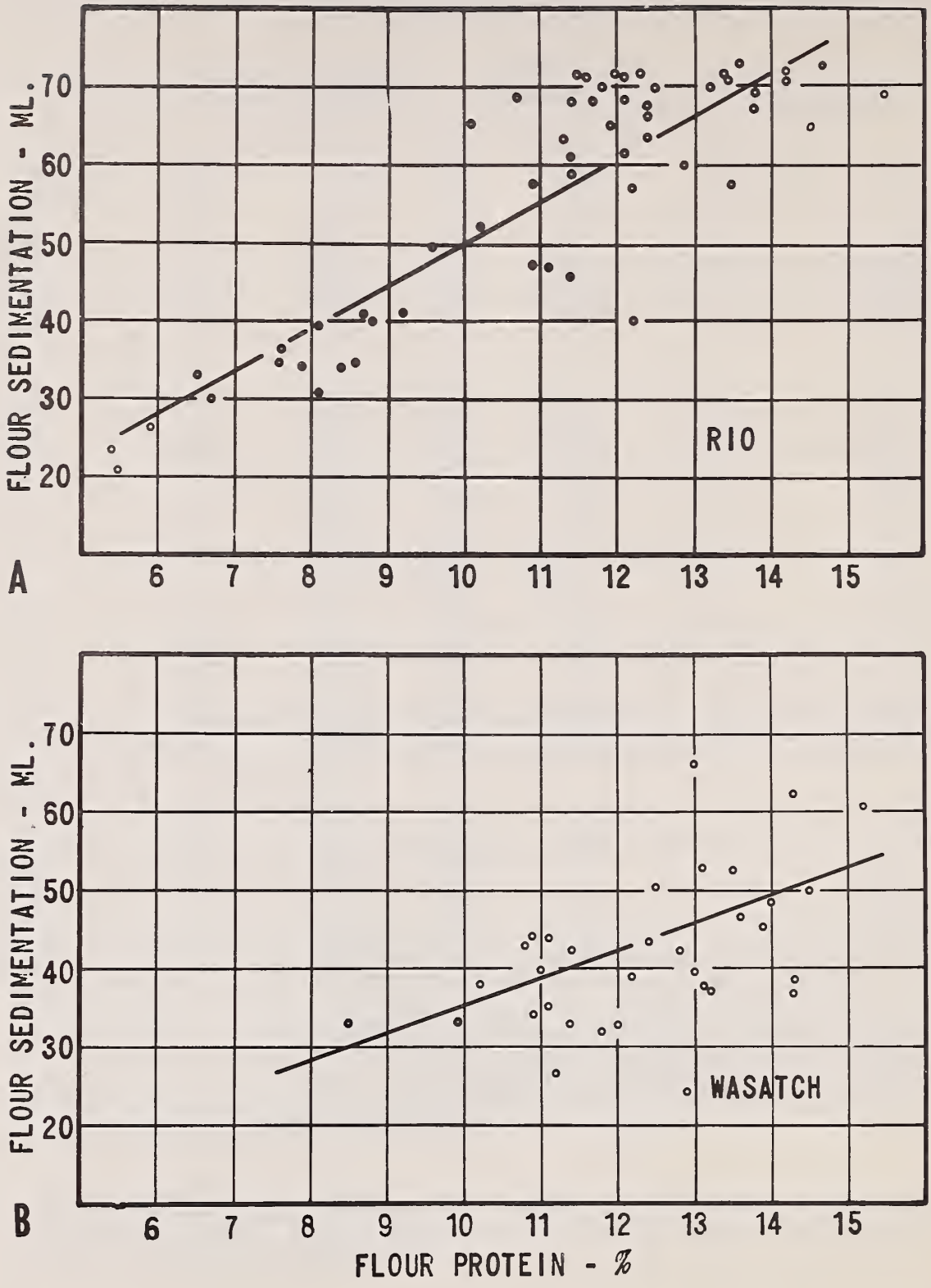

Figure 3.--Flour sedimentation values vs. flour protein content for the hard red winter wheat variety: A, Rio and B, Wasatch.

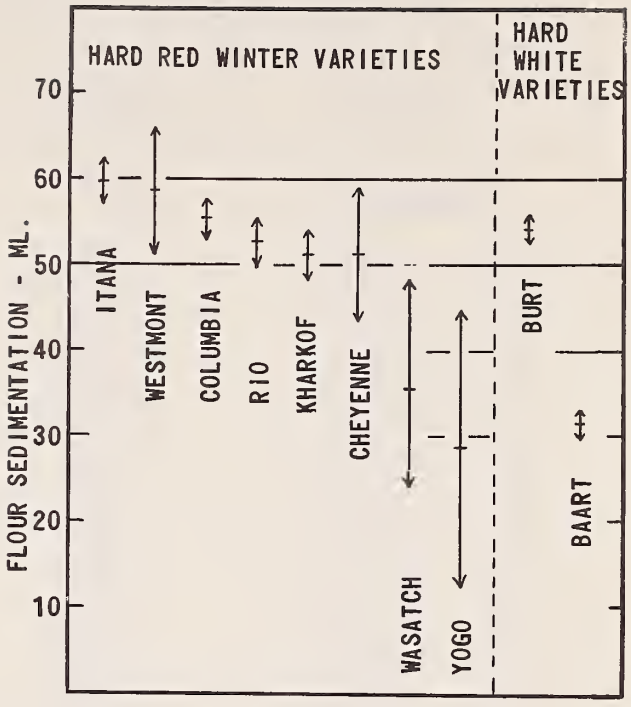

Figure 4.--Confidence intervals (at the 5-percent point) for flour sedimentation values at 10.5-percent flour protein content for the hard red winter and hard white wheat varieties.

TABLE 11.--Experimental mill-flour sedimentation of hard red winter and hard white wheat varieties

Type and variety	Samples	Correlation coefficient	Mean sedimentation	Mean protein	Sedimentation at 10.5-percent protein	Regression coefficient	Standard of error estimate
	No.		Ml.	Pct.	Ml.	Ml./Pct.	Ml.
Hard Red Winter Varieties:							
Itana	32	0.84**	65.2	11.5	[1] 59.9 ± 2.70	[2] 5.29 ± 0.64	6.49
Westmont	12	.80**	67.6	12.8	58.9 ± 7.47	3.80 ± .89	6.77
Columbia	40	.91**	59.1	11.1	55.5 ± 2.34	5.97 ± .44	7.10
Rio	47	.84**	55.1	10.9	52.9 ± 2.82	5.45 ± .53	9.51
Kharkof	38	.88**	51.3	10.5	51.3 ± 2.94	5.86 ± .53	8.89
Cheyenne	12	.74**	62.0	13.1	51.3 ± 7.81	4.11 ± 1.20	5.52
Wasatch	26	.61**	43.5	12.3	37.2 ± 11.39	3.51 ± 2.93	7.63
Yogo	9	.85**	56.8	13.8	28.9 ± 16.24	8.44 ± 1.98	6.68
Hard White Varieties:							
Burt	52	.88**	51.8	10.1	54.3 ± 1.83	6.21 ± .47	6.45
Baart	41	.77**	33.7	11.1	31.7 ± 1.83	3.27 ± .43	5.51

[1] Probability at the 5-percent level that the true sedimentation at 10.5-percent protein content will be in this range.
[2] Standard error of regression coefficient.
**Significant at 1-percent level.

Table 12.--Flour quality data for Rio hard red winter wheat

Flour protein	Flour sedimentation	Valorimeter reading	Mixing time	Loaf volume
Percent	Ml.	Units	Min.	Ml.
8.8	[1] 40.0	54	4.00	773
9.6	[1] 49.5	56	5.10	758
10.2	52.0	59	4.00	825
10.7	68.8	86	6.50	862
10.9	57.8	79	4.00	933
10.9	[1] 47.5	60	3.50	890
11.1	[1] 47.0	69	2.63	875
11.3	63.5	60	4.00	945
11.4	59.0	70	2.88	920
11.4	61.1	84	4.75	868
11.4	68.2	91	6.50	885
11.4	[1] 45.8	61	3.30	870
11.5	71.8	100	4.88	940
11.6	71.5	72	4.00	928
11.7	68.5	74	4.10	897
11.8	70.0	94	6.90	858
11.9	65.1	74	3.00	893
12.0	71.6	64	3.00	915
12.1	71.5	81	2.75	1,018
12.1	68.5	71	2.63	927
12.1	61.5	62	2.50	927
12.2	57.2	59	2.50	968
12.3	72.2	69	3.80	905
12.4	63.7	70	3.50	963
12.4	68.0	81	3.50	948
12.4	66.5	70	3.00	928
12.9	60.0	56	2.50	915
13.2	70.0	76	3.40	1,095
13.4	72.0	71	2.50	920
13.4	72.2	78	3.40	925
13.5	57.8	55	1.50	985
13.6	73.1	70	2.50	923
13.8	67.5	66	2.25	1,008
13.8	69.2	81	3.25	1,013
14.2	71.2	77	3.10	968
14.2	72.0	98	5.90	1,058
14.5	65.0	77	3.40	1,008
[2] 12.1	[2] 62.9	[2] 72	[2] 3.65	[2] 925

[1] Sedimentation similar to Wasatch at similar protein levels.
[2] Average.

Table 13.--Flour quality data for Wasatch hard red winter wheat

Flour protein	Flour sedimentation	Valorimeter reading	Mixing time	Loaf volume
Percent	Ml.	Units	Min.	Ml.
9.9	33.0	54	2.38	798
10.2	38.0	51	2.20	758
10.8	43.0	56	3.25	846
10.9	44.2	57	2.40	845
10.9	34.3	49	1.80	798
11.0	39.8	55	2.40	840
11.1	44.5	76	2.50	863
11.1	35.0	48	2.00	783
11.2	26.8	37	1.00	837
11.4	42.3	54	2.30	823
11.4	33.0	48	2.30	860
11.8	32.0	44	1.50	828
11.9	34.0	41	1.50	833
12.0	32.8	50	1.88	835
12.2	39.2	55	1.80	833
12.4	43.5	58	1.90	870
12.5	50.2	56	1.90	833
12.8	42.2	55	1.60	800
12.8	24.5	31	1.30	740
13.0	39.5	57	1.38	916
13.0	[1] 66.0	58	1.50	934
13.1	38.0	48	1.30	868
13.1	53.0	56	2.30	1,050
13.2	37.0	46	1.00	848
13.5	52.5	54	1.90	948
13.6	46.5	51	1.20	870
13.9	45.5	57	1.75	980
14.0	48.4	53	1.60	853
14.3	36.8	53	1.50	955
14.3	[1] 62.5	65	1.40	878
14.3	38.5	45	1.40	888
14.5	50.0	60	2.00	995
[2] 12.4	[2] 41.5	[2] 52	[2] 1.82	[2] 860

[1] Sedimentation similar to Rio at similar protein levels.
[2] Average.

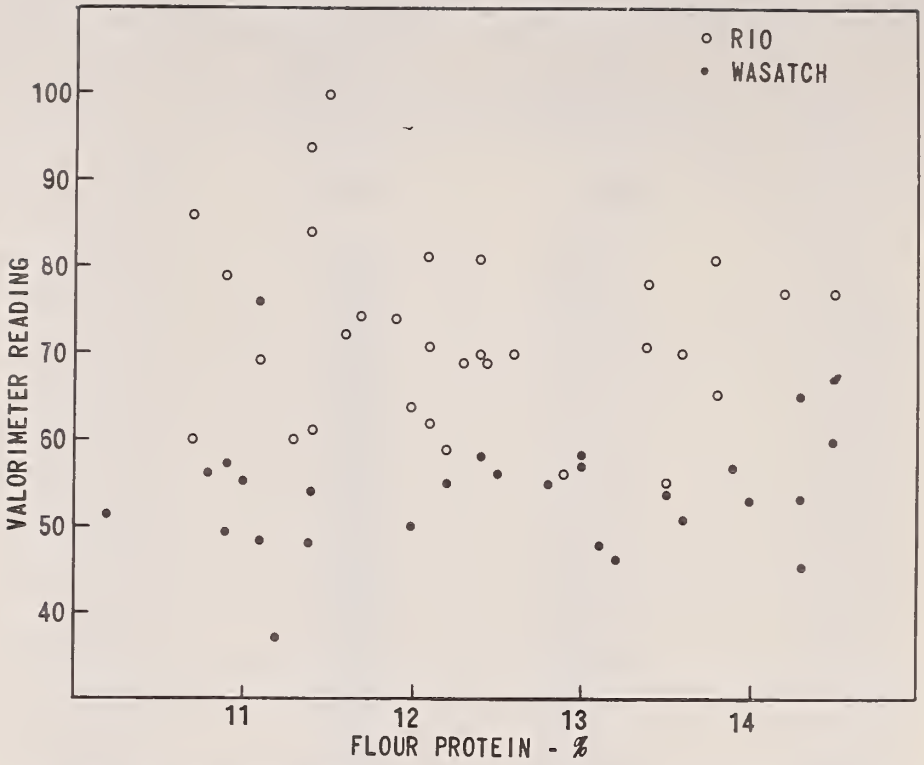

Figure 5.--Valorimeter reading vs. flour protein content for Rio and Wasatch.

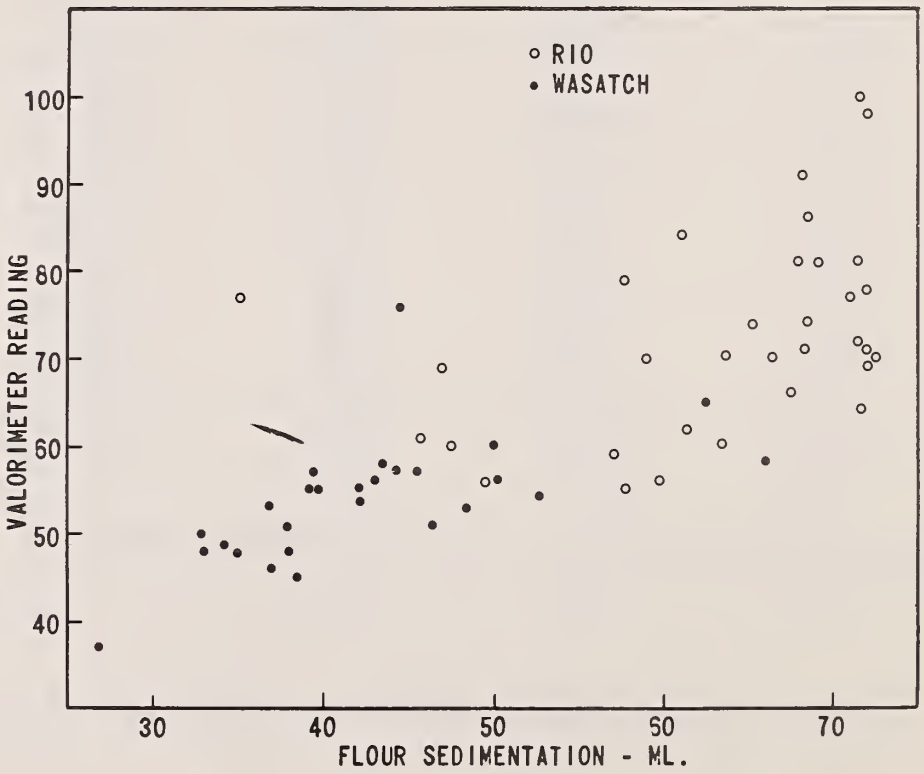

Figure 6.--Valorimeter reading vs. flour sedimentation for Rio and Wasatch.

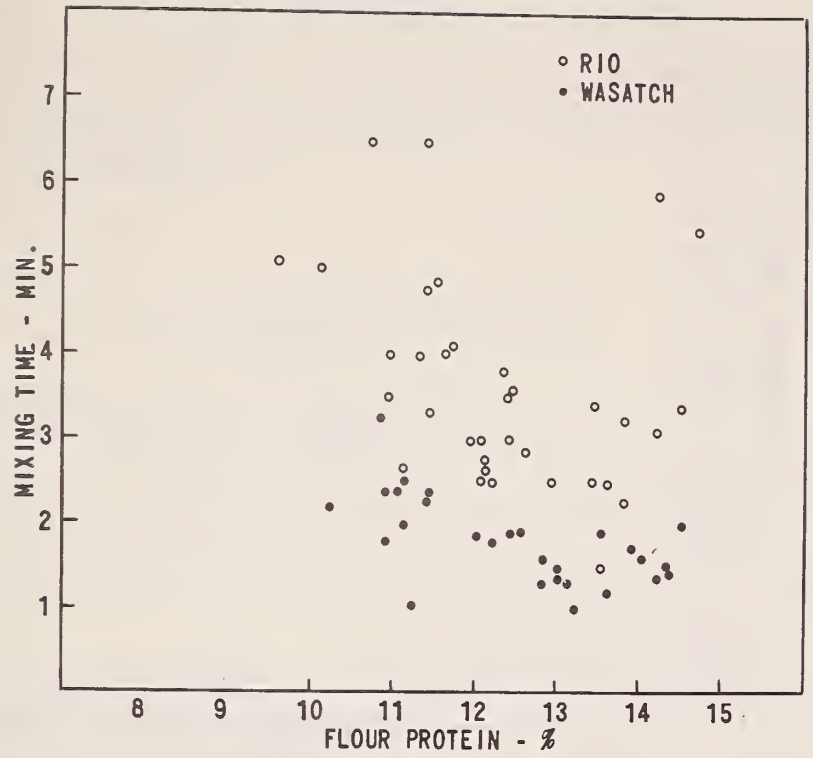

Figure 7.--Mixing time vs. flour protein content for Rio and Wasatch.

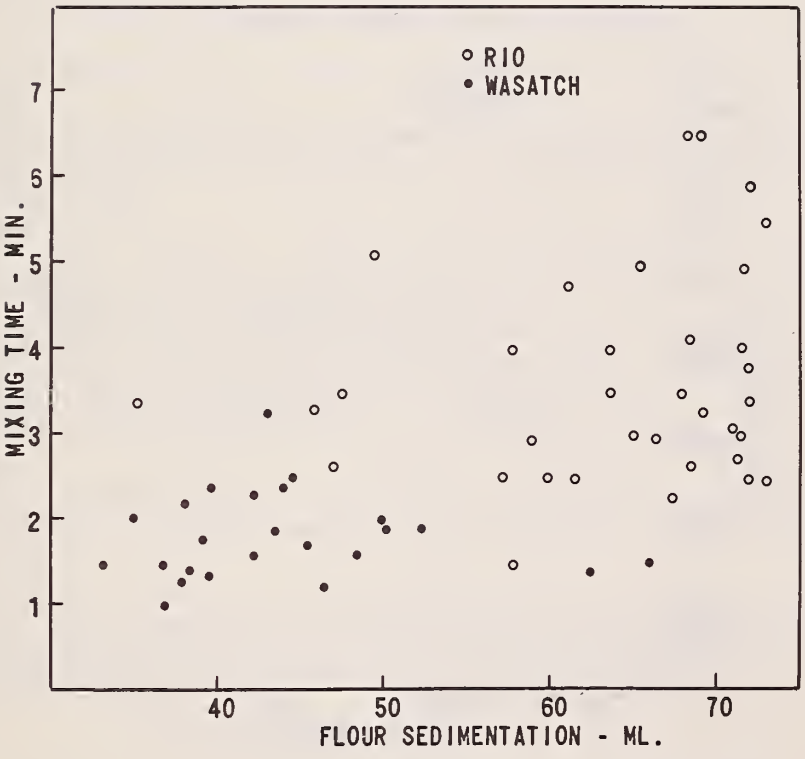

Figure 8.--Mixing time vs. flour sedimentation for Rio and Wasatch.

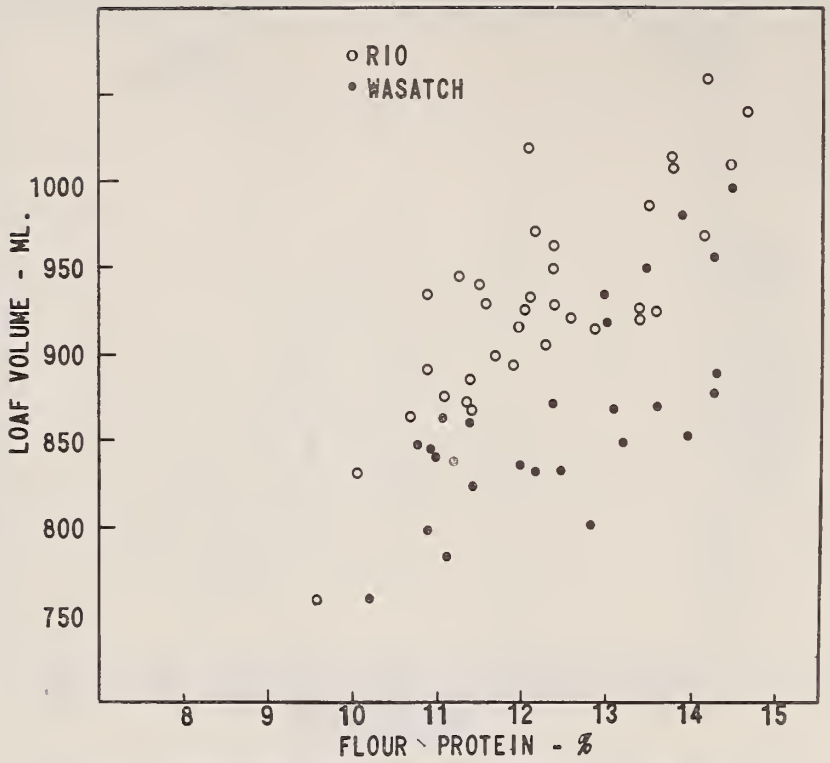

Figure 9.--Loaf volume vs. flour protein content for Rio and Wasatch.

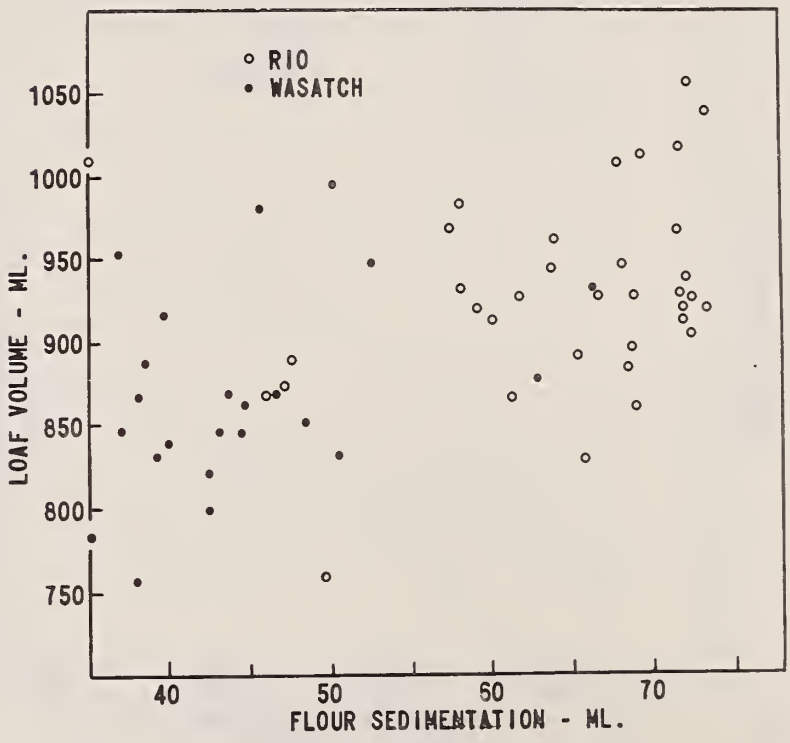

Figure 10.--Loaf volume vs. flour sedimentation for Rio and Wasatch.

SUMMARY

Studies on a number of varieties of hard wheat grown at experiment stations in the North Central and Pacific Northwest States have shown the value of both sedimentation and protein data in predicting bread-baking quality. The general conclusion based on these data is that both tests provide useful information.

LITERATURE CITED

(1) American Association of Cereal Chemists, Inc.
1957. Cereal laboratory methods. 6th Ed. St. Paul, Minn.

(2) Anderson, J. A.
1956. Grain research laboratory annual report. Dept. Trade and Commerce. Canada.

(3) Ausemus, E. R., and Reitz, L. P.
1962. Hard red spring and durum wheats--culture and varieties. U.S. Dept. Agr. Inform. Bul. 249, 24 pp.

(4) Barmore, M. A.
1957. A summary of the quality and protein content of western wheat varieties. Cereal Science Today 2: 162-165.

(5) Bequette, R. K., McNeal, F. H., and Potts, R. B.
1961. Field performance, quality characteristics of Montana spring wheat varieties. Northwest. Miller, September 18, pp. 22, 24-26, 28-29.

(6) Berliner, E., and Koopman, J.
1929. Uber die Kleberbestimmung in Weizenmehlen. A. ges Mulhenw VI: 33.

(7) Copp, L. G.
1956. A small scale quality test in wheat breeding. Nature 1770 (4512): 756-757.

(8) Crawford, W. N.
1947, Description and geographical distribution of the major wheat varieties of the Pacific Northwest wheat area in 1946. Pacific Northwest Crop Improvement Assoc. Bul. 2. Walla Walla, Wash.

(9) Crop Quality Council.
1960. Minutes of the milling and baking conference, December 20. Minneapolis, Minn.

(10) Fifield, C. C., Clark, J. A., Weaver, Ray, and others.
1945. Milling, baking and chemical experiments with hard red spring wheats 1944 crop. U.S. Dept. Agr. unnumbered mimeographed pub., 41 pp.

(11) _____, Weaver, Ray, and Hayes, J. F.
1950. Bread loaf volume and protein content of hard red spring wheats. Cereal Chem. 27: 383-390.

(12) Finney, K. F., and Barmore, M. A.
1948. Loaf volume and protein content of hard winter and spring wheats. Cereal Chem. 25: 291-312.

(13) _____, and Yamazaki, W. T.
1946. Water retention capacity as an index of the loaf volume potentialities and protein quality of hard red winter wheats. Cereal Chem. 23: 416-427.

(14) Fraser, J. G. C., and Whiteside, A. G. O.
1956. Handbook of Canadian spring wheat varieties. Pub. 538, Canada Dept. of Agr., Cereal Crops Div., Expt. Farms Serv., 47 pp.
(15) Haertlein, H.
1956. Behavior of the most important Argentine wheat varieties in the Zeleny sedimentation test. Getreide U. Mehl 6: 32-33. (Food Sci. Abs. 28: Abs. No. 1655.)
(16) Halton, P., Baker, G. J., and Jones, C. R.
1961. An examination of the sedimentation test. Milling 137 (26): 674-677.
(17) Harris, R. H., and Sibbitt, L. D.
1956. Relations between wheat protein content, loaf volume, expansion volume, and sedimentation value. 1. Plant breeder's samples. Cereal Chem. 33: 74-78.
(18) Mattern, P. J., and Eastin, Jerry D.
1962. Nebraska wheats evaluated with the sedimentation test. Cereal Sci. Today 7: 278-284.
(19) Miller, Byron S., Hays, Betty, and Johnson, J. A.
1956. Correlation of farinograph, mixograph, sedimentation and baking data for hard red winter wheat flour samples varying widely in quality. Cereal Chem. 33: 277-290.
(20) Nelson, W. L., Elliott, F. C., and Barmore, M. A.
1953. Henry, a new variety of spring wheat for reseeding in hard red winter for the Big Bend. Wash. Agr. Expt. Sta. Cir. 211.
(21) Northwest Crop Improvement Association.
1958. Minutes of the Minneapolis milling and baking conference, December 15.
(22) Pacific Northwest Crop Improvement Assoc.
1959. Quality wheats for the Pacific Northwest, production, handling, use. Spokane, Wash.
(23) Pinckney, A. J., Greenaway, W. T., and Zeleny, L.
1957. Further developments in the sedimentation test for wheat quality. Cereal Chem. 34: 16-25.
(24) Pratt, Jr., D. B., Thormby, Jack I., and Schlesinger, Jeff S.
1962. Correlations between sedimentation, protein, loaf volume and bake score. Cereal Sci. Today. 7: 244-247.
(25) Shellenberger, J. A.
1958. Survey of the quality of European wheat imports. Kans. Agr. Expt. Sta. Bul. 396, 117 pp.
(26) Sibbitt, L. D., and Gilles, K. A.
1961. Sedimentation values of hard red spring wheat varieties now being grown in North Dakota. N. Dak. Bimo. Bul. 22 (2): 22-23.
(27) _____ and Gilles, K. A.
1962. Sedimentation test as index of HRS wheat quality, 1. Some effects of grinding. 2. Some sources of variation. Cereal Sci. Today 7: 232-234; 236-243.
(28) _____ and Gilles, K. A.
1962. Justin: A new high quality, rust resistant wheat. II. Quality characteristics. N. Dak. Farm Res. 22 (5): 11-16.
(29) Zeleny, Lawrence.
1947. A simple sedimentation test for estimating the bread-baking and gluten qualities of wheat flour. Cereal Chem. 24: 465-475.
(30) _____.
1962. Wheat sedimentation test. Cereal Sci. Today 7: 266-230.
(31) _____, Greenaway, W. T., Gurney, Georgia M., and others.
1960. Sedimentation value as an index of dough-mixing characteristics in early generation wheat selections. Cereal Chem. 37: 673-678.